

ANUFLOOD IN NEW ZEALAND: PART 2  
Background to flood loss measurement

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## FOREWORD

This Working Paper is one of a set of three containing papers presented at a Seminar-Workshop entitled ANUFLOOD An Integrated Computer Package for Flood-loss Adjustment and Abatement held at the University of Waikato, Hamilton, New Zealand from December 11-13, 1985. The meeting was sponsored jointly by the Geography Department of the University of Waikato, the Water and Soil Directorate of the Ministry of Works and Development and CRES. ANUFLOOD is an interactive computer package developed in CRES and commercially available from ANUTECH at the Australian National University. It is designed to assess tangible urban damage and to evaluate the likely effects of a wide range of mitigation options.

The aim of the Workshop was to discuss the various forms of urban flood damage, possible mitigation strategies and the applicability of ANUFLOOD to flood problems in New Zealand. Some 25 participants drawn mainly from New Zealand Catchment Boards and the Ministry of Works and Development attended the Workshop. To provide data for a practical demonstration of ANUFLOOD the flood-prone parts of Paeroa, a town near Hamilton, were mapped. In addition to the demonstration five papers were presented at the meeting. Four of these were contributed by CRES staff and the fifth by the Workshop organiser, Dr Neil Ericksen of the University of Waikato.

The five papers, plus a summary of the Workshop conclusions, will be published in New Zealand by the University of Waikato in collaboration with the Ministry of Works and Development. Publication as CRES Working Papers will enable rapid initial circulation to interested workers in the field.

The papers are published as three linked CRES Working Papers under the general title of ANUFLOOD in New Zealand.

Part I (CRES Working Paper 1986/2) contains the paper by Neil Ericksen entitled Approaches to Urban Flood-loss Reduction in New Zealand.

Part II (CRES Working Paper 1986/3) Background to Flood Loss Measurement comprises two papers by John Handmer.

Part III (CRES Working Paper 1986/4) ANUFLOOD Development and Application consists of two papers by David Ingle Smith. These provide a background to the use of ANUFLOOD as presented in the programmer's guide and user's manual.

Enquiries concerning the availability of the Seminar-Workshop Proceedings should be sent to:

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Details regarding the availability of ANUFLOOD should be directed to David Ingle Smith at CRES or to:

ANUTECH Pty Ltd  
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Canberra City, 2601

The authors would like to acknowledge the value of the discussions at the Workshop with representatives of the Water and Soil Directorate of the Ministry of Works and Development and staff from a number of New Zealand Catchment Boards.

**ABSTRACT**

This Working Paper examines the main theoretical and methodological issues surrounding urban flood damage assessment. The first section defines the terminology used in flood damage measurement, explores some of the underlying concepts and introduces important elements of the relevant economic theory. The two main approaches to measurement, that based on historical and that using synthetic stage damage curves, are examined in the second section. Also, issues particularly relevant to indirect and intangible damage assessment are presented. An appendix sets out one approach to the measurement of intangible flood losses.

**KEY WORDS:** Flood damage assessment; urban floods; direct damage; indirect damage; intangible damage; economics of floods; stage damage curves.

**ACKNOWLEDGEMENTS**

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PART A  
MEASURING FLOOD LOSSES: GENERAL ISSUES\*

**INTRODUCTION**

This paper sets out some basic terminology used in flood damage assessment. Where appropriate the underlying concepts are explored. The critical elements of economic theory are also introduced, though it is stressed that these are not dealt with in depth.

**TYPES OF FLOOD DAMAGE**

Flood losses are referred to as direct when damage is caused by the physical contact of property with flood water or debris, and indirect when the losses result from the disruption of normal economic and social activities. Indirect damages may occur during or after the flood, and may include disruption to schooling, transport, trade, industrial or agricultural production, tourism, and the cost of flood fighting and cleaning up. These two major categories of loss are further subdivided into tangibles and intangibles according to whether or not the items can be valued in conventional economic terms. Tangible damages can be valued in monetary terms, while intangible losses concern items that are not normally bought and sold and for which market values do not exist. Direct intangible losses would include death from drowning, and the destruction of cultural artefacts and personal memorabilia. Examples of indirect intangibles are death or ill-health resulting from flood induced stress, and disruption to schooling. Table 1 sets out the damage classification with examples.

In much of the literature the terms "direct" and "indirect" refer to tangible losses only and no distinction is made between direct and indirect intangibles. Thus damages are categorised as direct, indirect or intangible.

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\* Unless shown otherwise all prices are Australian dollars.



Table 1: Classification of flood losses.

| MEASUREMENT                                   | TYPE OF LOSS   |   |
|---|--|---|
|   | DIRECT<br>(physical contact<br>with flood water)   | INDIRECT<br>(flood induced dis-<br>ruption or stress)   |
| <b>TANGIBLE</b><br>(monetary<br>values)       | Damage to infrastructure,<br>buildings and contents,<br>vehicles, boats, etc.                | Loss of production, clean<br>up costs.  |
| <b>INTANGIBLE</b><br>(non-monetary<br>values) | Death by drowning, loss<br>of items of cultural<br>significance and personal<br>memorabilia. | Inconvenience and<br>disruption, esp. to<br>schooling and social<br>life. Stress induced<br>ill-health and mortality. |

#### Special categories of tangible direct damage

**Caravan Parks** Caravan parks are frequently excluded from flood damage evaluations, but deserve special mention. Many Australian caravan parks are located in very flood prone locations. The Lismore (New South Wales) Council park for instance is subject to annual flooding. Even though such parks frequently have adequate evacuation plans, if only rehearsed due to constant flooding, the disruption and anxiety caused to residents would greatly increase indirect and intangible damages. Caravan parks with less experience, where a proportion of vans is typically immobile, are not organised for rapid evacuation and substantial direct damage may result.

**Vehicles** Vehicle damage may be large as most Australian households own at least one car, truck etc. The extent of these losses is shown by the experiences of Brisbane and Florence, and the Adelaide potential flood-loss estimates. Vehicle damage in the 1974 Brisbane flood amounted to 6% of total direct residential and public utility damage (SMEC, 1975), while 15,000 cars were destroyed by the 1966 Florence flood (Clark, 1983). In the Adelaide potential flood-loss study, car damage was typically assessed at between \$1,500-\$2,000, and occasionally exceeded that to residential contents (SMEC, 1980) (see Smith, 1986). It is stressed that the Adelaide figures are estimates of what would happen if

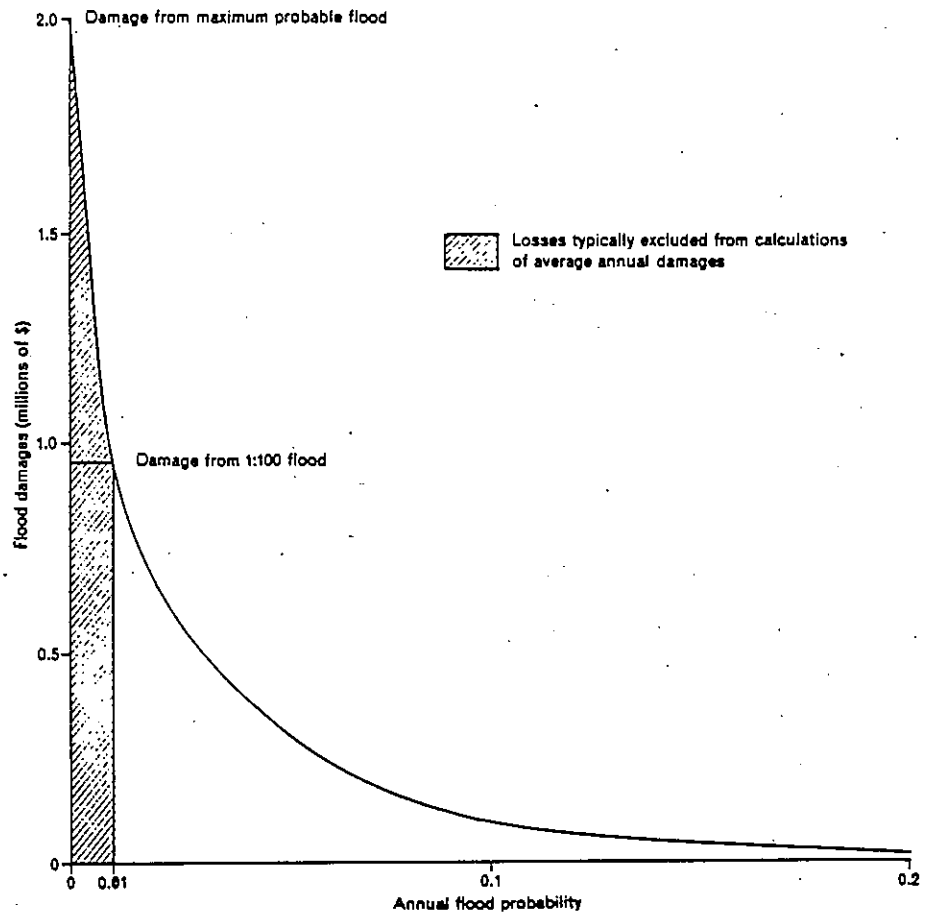


Figure 1 : Flood damage by probability for a hypothetical site.

the area was flooded, they are not historical flood losses (see Part B). As with losses to household contents vehicle damage is likely to be especially high where the population is inexperienced and warning time limited, though it is stressed that the salvage value of vehicles is often high.

#### EXPRESSING THE LOSS

Flood damages may be expressed as the experienced or expected loss from a single specified event, or event damage. While this provides information on the likely loss from say a very low probability flood or an historic event, it does not enable economic assessment of mitigation schemes.

The use of average annual damage estimates avoids this shortcoming. These are obtained by summing for all floods the products of flood damage by flood probability, more generally expressed as the integral of the area under a flood damage by probability curve. Unfortunately, all too frequently losses are only calculated up to the regulatory flood, usually the 1:100 event. This may exclude a substantial proportion of the average annual damage. The diagram in Figure 1, representing the flood damages by probability curve for a hypothetical town, illustrates the point. For Lismore the average annual residential damage calculated to the maximum probable flood (MPF) level is approximately 13% greater than that calculated to the 1:100 level. The difference between damages estimated to the two heights may be substantially greater in other towns, or if commercial damages are included in the analysis. At Forbes, NSW, for example, average annual losses to the residential and commercial sectors combined are approximately one third greater if calculated to the MPF rather than 1:100 level (SKP et al 1982: A1.10). Moreover, both these examples exclude that development lying between the 1:100 and MPF levels.

Frequently, MPF height information is not available and in its absence accurate average annual damage estimates cannot be obtained. In such cases a conservative estimate should be applied; failing that some of the additional damages may be included by assuming that the MPF is the same height as the 1:100 event. It is clear from Figure 1 that whatever the real height of the MPF, the area bounded by the height of the 1:100 event and the probabilities of the 1:100 and MPF is part of the average annual damage. However, the area may contain relatively little of the extra loss. This is because flood depths remain at the 1:100 level, and this same water depth is being integrated over very low probabilities.

For a mitigation project to be economically viable, benefits (in terms of flood damages avoided) must exceed project costs when both costs and benefits are reduced to some common base for comparison. Project costs may be amortised over some given period for comparison with average annual damages. However, it is more usual to adjust flood damage estimates. Costs for flood mitigation strategies are usually calculated at their present value (exceptions may include acquisition schemes, warning schemes and other activities with high recurrent expenditure).

Benefits are typically spread out over the expected life of the project as a series of annual damages avoided. This series of benefits may be capitalised or converted to a present value using the formula:

$$\text{Present value} = \frac{A}{i} \left[ 1 - \left( \frac{1}{1+i} \right)^N \right]$$

where A equals the average annual benefit, i is the discount rate and N the expected project life (Penning-Rowsell and Chatterton, 1977). Clearly the discount rate constitutes a particularly sensitive part of the calculation as small variations in i will substantially alter the present value (see Figure 2). Selection of an appropriate rate is often controversial. Sometimes governments specify the rate to be used as in the UK where 5% is used for assessing all government assisted works. In Australia a rate has not been made mandatory, but 10% has typically been adopted for major flood mitigation projects. A different approach is advocated by Lustig (1984) based on work by Marglin (1976) and Major (1977). He argues that the discount rate should vary according to the objectives (p173).

"Thus for business, the discount rate might be 10 to 15%, being around the pre-tax rate of return on investment less inflation... For the consumer, the return on investments has recently been around 0 to 7% when inflation is accounted for... In the evaluations of flood mitigation works therefore, the discount rate for a particular project could be calculated according to the relative weights of the business, rural and residential beneficiaries".

Whatever approach is adopted, the sensitivity of capitalised average annual losses to discount rate variations should be shown.

Presenting expected flood damages solely as average annual estimates may obscure from decision makers the possibility of catastrophic losses from a rare event. It may also fail to indicate the impact of different mitigation strategies on floods of different magnitudes. This relates to the earlier comment on the level of the regulatory flood. The likely damage from an event which exceeds the design limits of the mitigation project should be shown. Event damage may be very large even though the average annual remaining or residual damage is very low. Residual damage is the area under the curve in Figure 1 lying between the design limit of the mitigation project and the MPF.

It is recommended that reports presenting the results of flood damage assessments should show the following information:

- the average annual damages avoided by the proposed measure
- the probable "worst case" damages with and without the measure, and
- the average annual residual damage with the measure.

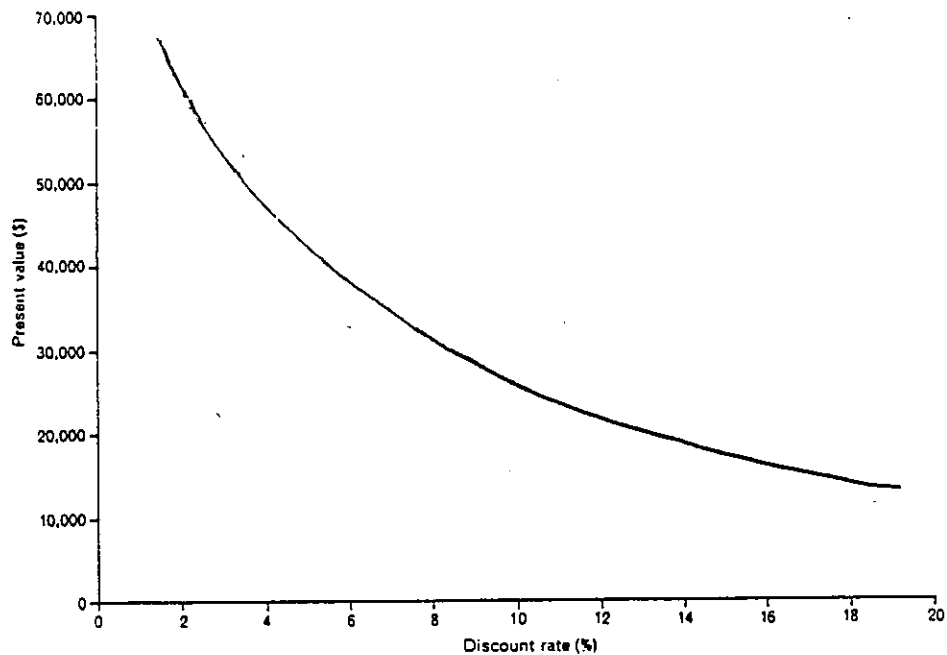


Figure 2 : Sensitivity of Present Value Calculation to the discount rate. Time period is 30 years. Average annual damage = \$2724.

## WHAT CONSTITUTES LOSS?

Assessment of tangible direct loss is relatively straightforward. Such losses are also often the most visible, which may be why both researchers and the responsible government authorities have devoted most attention to the assessment of direct damages.

In economic terms direct losses to the nation result from damage to assets during their economic life. This applies to both tangible and intangible assets. Society incurs loss because it loses part of its capital stock, and because resources must be diverted from other productive activities to replace or repair the assets. In the reconstruction period after a flood disaster the local or regional economy may gain considerably from the increased construction work and sales of new furniture etc. But, it is important to bear in mind that money not spent on assets replacement would be available for something else, and that while the local economy may benefit from disaster-assistance funds and tax relief the state or national economies may be worse off.

In general terms, tangible direct losses are defined as the difference in value between the pre and post flood condition of damaged items. Thus the damage to structures is the cost of repairs necessary to regain pre-flood condition, while damage to contents is valued as the cost of restoration to pre-flood condition, ie the cost of new items minus depreciation. The procedures developed by Penning-Rowell and Chatterton (1977) and used in Britain calculate tangible direct losses in this fashion. In the British method the cost of new household items (replacement value) is halved to allow for depreciation.

Indirect losses are very much harder to assess and are often ignored or obscured. Damages may result from loss of productivity on a farm or other commercial enterprise, or from a negative impact on social welfare. Only those damages which are not made up elsewhere within the nation count as losses to the country. "Where one person's loss results in another person's gain income is redistributed but if the gain equals the loss there is no change in (economic) efficiency" (Green et al, 1983:71).

This concept of transferability is a central issue in the determination of indirect losses but is rarely significant in direct damage assessment. Although one company's loss of equipment will lead to another company selling replacement equipment, this transfer still results in economic loss. Loss occurs because the replacement equipment "would otherwise have been sold to another company to produce goods with a resultant net increase in national production" (Green et al, 1983:71).

#### COMPONENTS OF FLOOD DAMAGE

Components of flood damage are set out in Table 2. Many of the factors are closely linked and the distinction between physical and human aspects is not clear-cut. For example, the importance of preparedness is linked to warning time. As well, the importance of individual components varies greatly, in mountain areas and small urban catchments short warning times and water velocity would be the critical factors. Material transported by flood water might be an additional important factor increasing the damage potential, debris in the case of the mountain stream and oil or other pollutants in the urbanised catchment. With short warning times preparedness is of great importance. In turn, certain socio-economic factors, the state of the emergency services and ease of evacuation will affect ability to respond rapidly to warnings. By contrast water depth and flood duration are two of the critical damage factors in Australian inland flooding. The long periods of isolation associated with such flooding (occasionally in the order of months) increase the potential size of indirect losses, and highlight the importance of flood free access.

Stage damage curves, the basis of most urban flood damage assessments (see Smith, 1986), usually consider only depth of inundation, although in the case of historically derived curves other factors may be incorporated (by accident rather than design). The 1985 NSW draft Floodplain Development Manual (NSW-FPRC, 1985) is one of the few attempts by a government authority to incorporate human as well as physical factors into flood hazard analysis.

Table 2: Components of tangible and intangible flood damage. Note that the physical/human distinction is not clearcut, for example (iii) is influenced by upstream land-use patterns.

#### PHYSICAL

- (i) Water depth.
- (ii) Water velocity
- (iii) Debris, sediments and pollutants carried by the water, including sea water.
- (iv) Flood duration; of varying importance in urban flood damage, but critical for rural damages. In both urban and rural situations long inundation periods (> 1 week) greatly increase the intangible costs of flooding (SKP et al 1982).
- (v) Flood warning time and rate of rise of flood water; is critical in safety considerations and if the warning time is very short (< 6 hours) may outweigh most other flood damage components. It is also a critical factor in contents (as opposed to structure) damage as a determinant of the amount of contents relocation possible. Warning effectiveness is largely a function of message dissemination and individual preparedness.
- (vi) Isolation; the extent to which the area becomes isolated with resultant access difficulties during floods. The importance of this factor is closely associated with warning time.
- (vii) Occurrence probability; not a component of flood damage but is necessary when information is required on average annual damages.

#### HUMAN

- (i) Preparedness; at the individual and community level. It is largely a function of experience.
- (ii) Emergency services; efficiency is closely related to preparedness and is particularly important where warning time is limited.
- (iii) Ease of evacuation;
- (iv) Socio-economic status; groups such as the aged, and infirm, especially if single, and single parent families are less able to respond to warning effectively, while the poor tend to lack the financial resilience and political power necessary to cope with disaster.
- (v) Structure characteristics



In general, at urban sites flood velocity and depth are the critical physical factors for potential damage and risk to life, unless a flash flood potential exists. Flood duration is generally not important for urban damages, and while debris and water-borne pollutants occasionally constitute a health risk they are of a highly unpredictable nature. Individual and community preparedness is a key human determinant of flood loss and degree of hazard. Preparedness, which itself appears to be largely a function of experience, leads to more appropriate warning response and evacuation behaviour (SKP et al 1982). Other social or cultural factors relate to the floodplain occupiers' socio-economic status. For example, certain groups such as the poor, aged or infirm are less likely to respond effectively to warnings.

### **Preparedness and warning time**

The state of community preparedness and the available warning times appear to be the critical factors in deriving actual damages from the potential damage estimates provided by synthetic stage-damage curves.

Flood warnings on their own do not reduce damage. Rather they provide the opportunity for other activities to be put in train (Higgins and Robinson, 1981:12). Clearly, the effectiveness of warning response will depend on community preparedness (itself a function of experience). Warning time is also important because a lengthy lead time allows a community to prepare itself.

In an inexperienced community with a relatively short warning time (less than 24 hours) actual losses would be approximately equal to potential. Members of the community would be unaware of appropriate post-warning response and the warning time would be insufficient to inform them by demonstration.

At the other extreme in an experienced community or a settlement with a very long warning time potential damages can be reduced substantially. For example, Smith (1981) found that actual damage in Lismore consisted of 52.4 and 23.5 per cent of potential damage for the residential and commercial sectors respectively. Lismore is a very experienced and well prepared flood-prone town with about 6-12 hours warning of a major flood (Handmer, 1984).

These important issues are discussed further in Smith (1986).

#### ISSUES OF ECONOMIC EFFICIENCY

It is not suggested that strict adherence to the concepts found in economic theory is necessarily the best way to calculate flood damages. Nevertheless, if cost-benefit or cost-effectiveness analyses are to be performed practitioners should at least be aware of the relevant aspects of economic theory.

The correct application of economic principles is particularly important when calculating indirect damages, and is essential if knowledge of the most economically efficient floodplain land use is required. Some of these principles help avoid double counting. It is important to distinguish between economic and financial losses; and to remove transfer payments from the analysis, losses which become someone else's gain. Thus we need to be clear about the geographical area analysis applies to: is it the nation, local government area or some other jurisdiction? It is also important to consider the time-frame of the analysis. Are flood losses to commerce made up some months later? Were there special circumstances which made the losses illusory? Finally, the question of stock versus flow or capital versus income needs to be considered. To what extent are capital and income measures of the same thing?

#### Economic efficiency

Within the context of welfare economics a theoretically efficient allocation of resources must satisfy three criteria all related to the concept of Pareto improvement (Thompson et al, 1983:12):

- a. Efficient consumption: goods are allocated between consumers so that a reallocation cannot produce a Pareto improvement, which means that while some people may be made better off, no one will be made worse off.
- b. Technically efficient production - a reallocation of inputs cannot increase the output of one good without reducing the output of another.

- c. Efficient Product-mix: a. and b. are combined so that a reallocation of inputs cannot alter output and hence consumption without making at least one person worse off.

If these criteria were applied strictly to flood related land-use decisions or cost-benefit analyses most would fail the test, because inevitably major change will make someone worse off. To overcome this difficulty economists have weakened the economic efficiency test from a Pareto improvement to a potential Pareto improvement (Mishan, 1972:14):

A potential Pareto improvement is, then, defined as a change which - if costless transfers of goods and/or money among members of society are assumed - can make everyone better off. It is, in other words, a change which produces gains that exceed in value the accompanying losses; a change, therefore, such that gainers can (through costless transfers) fully compensate all the losers and remain themselves better off than before.

An obvious major shortcoming of this approach is that distributional effects are ignored. It is most important, therefore, that the differential impacts of a project on different social groups be identified and shown alongside the results of the economic analysis.

Where floodplain land use is concerned efficiency means that the use should produce the highest real return to the economy. To satisfy the criteria when assessing flood damages we need to consider a number of points.

#### **Economic or financial loss: the spatial extent of analysis**

Flood losses experienced by individual enterprises are known as financial losses. Apart from direct damage, financial losses include any business lost to a competitor either temporarily or permanently as a result of flooding. For the loss to be considered economic however, it must effect the economy of the region of analysis, for example the nation. Thus as a first step in deciding whether indirect tangible losses are real economic losses or simply losses to individual businesses it is necessary to delimit the spatial extent of analysis. We need to be sure

that one businesses' loss is not offset by another's gain. Such transfers within the region of analysis redistribute income but may not result in a loss to the region's economy.

Figure 3 illustrates the issue. In figure 3(a) there is no economic loss to the nation although there is a financial loss to company x: the products of company x (inputs to company y) can be supplied at short notice by another Australian company. However, if we redraw the boundary of analysis as in figure 3(b) there is an economic loss to the state of NSW as well as a financial loss to the company: the needed products came from a competitor outside the state. In both examples an economic loss would have occurred if there was no alternative supply of the needed products, or if the alternative supplier was overseas.

An important factor when assessing flood losses in a small region, for example a local government area, is the extent of state and federal government aid and insurance payments. At the national level such payments are simply transfers and can be ignored. In contrast, at the local level they may offset some of the flood losses and the estimates of economic damage should take these into account.

#### Time frames

In some respects the time-frame for flood loss calculation may be as critical as the spatial extent of analysis. Are we interested in the immediate losses to the region or the survival rate of small businesses one year later; the apparent losses to a furniture factory or whether the lost production was made up six months later; damage to infrastructure or its repair by government grants from outside the region sometime after the event; the extent of the effects of disrupted schooling; how long the stress of being flooded affects people; and so on? The time-frame issue is of greatest concern with assessment of intangibles and with tangible indirect damages.

To illustrate the assessment problems I will draw on an example provided by the insurance industry (Rowley, 1985). In this example the damaging event was a fire but the same principles would apply if the event had been a flood.

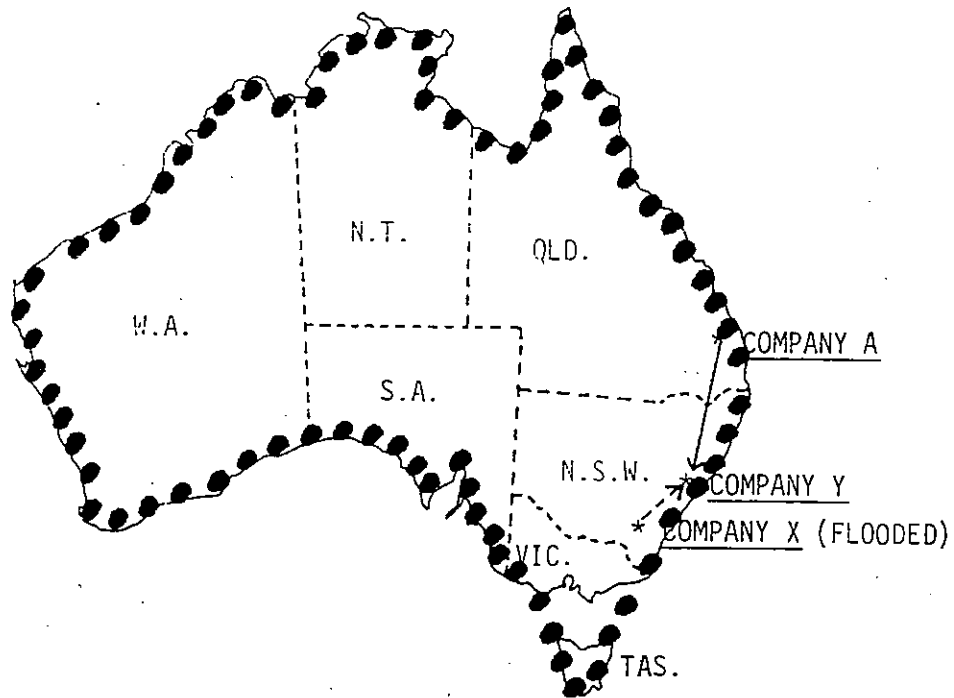


Figure 3(a) : Australia as the spatial extent of analysis. The products of company X are inputs to company Y. However when X is flooded Y can obtain the needed inputs from A at a higher transport cost. As all companies are in the area of analysis the cost to the economy is the additional transport charge.

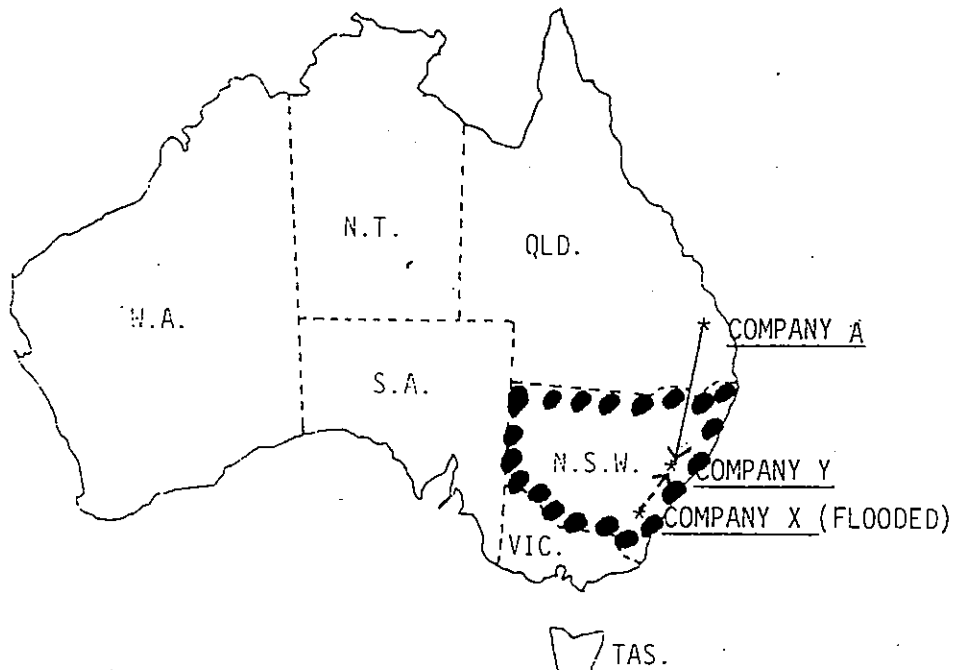


Figure 3(b) : N.S.W. as the spatial extent of analysis. In this case company A is outside the area of analysis, and the cost to the economy is the cost of the goods produced by A and imported into N.S.W. by Y.

As a consequence of this event, there was a loss of production amounting to several thousand tonnes of alumina with a potential Business Interruption (indirect damages) claim running into seven figures. The Business Interruption cover had a 12 Months Indemnity Period (the time frame for analysis). The Insured had another older less efficient alumina refinery and within four months of the loss event an announcement was made that it was cutting back production at this less efficient alumina refinery. At the time of this announcement all sales contracts had been fulfilled, and I took the view that the Business Interruption claim would be restricted to the Increased Cost of Working calculated on the differential cost of producing the same tonnage of alumina at the less efficient refinery compared with the lower production cost had the same tonnage been produced at the more efficient refinery where the loss had occurred. The logic here was that the less efficient refinery might have been able to shut down the same number of tonnes earlier had it not been for the interruption at Refinery 'A'.

To the extent that this loss was not made good by another company within the region of analysis it represents a real economic loss. To take the example further.

Subsequently, however, the world aluminium industry went into a deeper recession, and the company was forced to cut back one of the production units at Refinery 'A'. As this cutback took place within the 12 Months Indemnity Period, the Insured then acknowledged that they would not be in any position to substantiate a claim which would reach the deductible under their policy.

It is important to note that in this case any export losses already sustained by the economy remain as a real loss even though there is no basis for an insurance claim.

#### **Stock versus flow**

Milliman (1984) argues that indirect flood losses have frequently been overestimated because two alternative measures of flood loss, stocks and flows, have been treated as measures of different losses. "Stock" refers to capital (equipment, inventories and other physical assets), and "flow" refers to production flow or income.

Direct flood damages to factory equipment are losses to the nation. But, to avoid overestimating damage the cost of replacement must

be devalued by the depreciated value of the machinery. On average, we might assume that equipment will be halfway through its economic life, so destruction by flooding would incur stock damages equal to 50% of the replacement value. Similarly the equipment's remaining production flow would be about half that of new machinery. Counting both stock and flow losses in this example would be double counting because the cost of machinery (stock) is considered equivalent to the income it is expected to produce (flow) (Milliman, 1984).

Industrial enterprises are highly variable so it is most appropriate to analyse each firm separately. Losses may easily be distorted if an averaging approach is followed. For example a particular piece of equipment, written off in a flood, may have been well past its economic life, or replacement equipment may introduce new technology, improving the firm's productivity. The final damage estimate should be adjusted for such factors. The financial loss to the firm will include machinery damage plus some flow costs for time out of production, though the real cost of "down time" is highly variable (see previous section). "Down time" costs will not constitute economic losses, provided the lost production can be made up by another firm within the region of analysis or made up by the same firm within the time frame of analysis. However, "flow" losses might be incurred in addition to the stock damage if the firm's production shortfall leads to increased imports or decreased exports. When imports are involved the national loss will equal the "value added" component of the flooded firm's production. Both stock and flow aspects of flood damages need to be clearly specified to avoid double counting.

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**PART B**  
**APPROACHES TO FLOOD DAMAGE ASSESSMENT**

**INTRODUCTION**

This paper examines the two main approaches to estimating potential flood damages, and then explores issues surrounding assessment of indirect and intangible losses. An appendix contains details of one approach to assessing intangibles.

**DAMAGE ASSESSMENT: HISTORICAL OR SYNTHETIC STAGE DAMAGE CURVES?**

The various approaches used for loss assessment fall into one of two general categories: "historical" or "synthetic". In both categories damages are often presented as stage-damage (depth-damage) curves. These give the average damage sustained by a property in a specified property class, at different depths of overfloor flooding (Smith 1986). Stage-damage curves enable extrapolation of historic damage estimates to different flood heights, and are essential to synthetic damage assessments.

**The Historical Approach**

For an historical damage assessment, people who are thought to have incurred flood losses are interviewed to ascertain the extent of the loss. Often this will involve taking a sample of households or enterprises and generalising the results to the flooded population. In its simplest form damages may simply be treated as an aggregate figure, and no attempt made to differentiate them by type of activity (residential, commercial, etc), structure, and contents. Where a substantial number of properties are involved a more sophisticated analysis is usually attempted and stage-damage curves are constructed for different activities and structure types. The procedure is summarised in Figure 1. Australian studies employing the latter approach include SMEC's (1975) study of Brisbane, and the work of Smith et al (1979) in Lismore.

An important aspect of historical damage assessment is that the results are actual damages: that is, losses experienced at one point in time, given the community's preparedness, length of warning and so on. Unfortunately this fact is often neglected when estimates are transposed through time and extrapolated for larger floods. While this is a serious shortcoming, it means also that the estimates will represent the losses from the flood in question accurately, within the constraints imposed by the questionnaire methodology employed. This raises another issue: the method cannot be used where a flood has not occurred recently (say within 5 years of the date of survey), and can become very expensive where a large survey is involved.

### **The Synthetic Approach**

In its purest form synthetic damage assessment involves detailed land use mapping and inventories of property contents for different structure types. Stage-damage curves are synthesized for properties having similar susceptibility to flood damage. The contents component of commercial and residential curves is constructed by estimating the flood susceptibility of items kept at different heights within the dwelling or shop, while structural damage is derived from estimates of the cost of repairing flood damage to building fabric. The accuracy of the method depends therefore on the depth of the data bank. Unlike the historical damage evaluation, a synthetic assessment results in potential damage, where no account is taken in the initial calculation of warning time, population preparedness and emergency action. Hence a major issue in the use of a synthetic approach is the conversion of potential into actual damages, ie into those damages that might reasonably be expected in the community under study. Figure 1 sets out the steps in this form of damage assessment.

A synthetic approach for tangible direct damages is widely employed in the UK using the procedures set out by Penning-Rowell and his co-workers (Penning-Rowell and Chatterton, 1977). The UK method contains 21 basic categories for residential property subdivided by the social class (income) of occupiers, age of property, and flood duration to give 80 different residential stage damage curves. The British procedure also contains curves for commercial property.

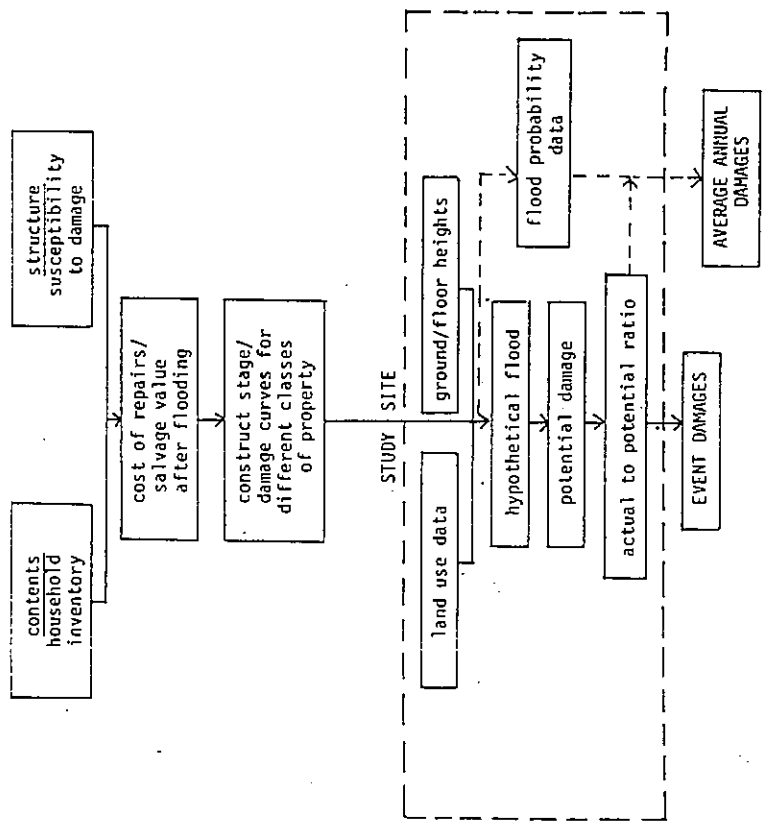


Figure 1(a) : Flood damage assessment using a synthetic approach.

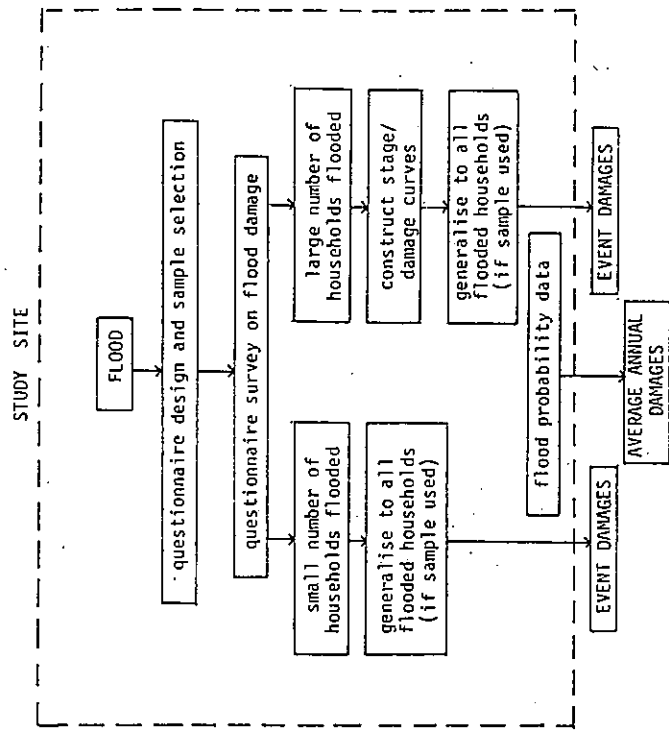


Figure 1(b) ; Flood damage assessment using historic damages.

In Australia a damage assessment procedure based on synthetic stage-damage curves for residential and commercial property is available as an interactive computer package; "ANUFLOOD", from CRES, ANU. In this form very substantial time and hence money savings are attained in damage assessment. No questionnaire surveys are required except for large commercial and industrial enterprises. A detailed land use survey is required, but this can be completed quickly and accurately.

Other major advantages of a synthetic approach are that:

- damages can be calculated for any flood in any community on a standardised basis. This is valuable where a flood has not occurred or where the last flood is beyond the reliable memory of most inhabitants
- there is a consistent appraisal of flood damages, especially important in setting priorities between schemes, also scheme benefits are less likely to be exaggerated
- sensitivity analyses are easy and quick to perform
- other advantages concern problems inherent in questionnaire surveying (eg sample selection, question wording and order, respondent recall).

Two major disadvantages are apparent:

- the first has already been mentioned and concerns the difficulties in determining actual damages from the estimated potential losses.
- the other problem is that by its nature as a standard methodology it is probably never totally appropriate to local conditions. It is felt that this is not a serious shortcoming except where "flash flooding" or dam burst situations exist. In these events structural damage is often very high. "Nearly 75% of all buildings are destroyed during flash floods" (White, 1975:28).

A related issue is that the method, again because it is standardised, tends to redistribute losses away from extremes. This averaging mechanism may have considerable merit, given that the costs and benefits of flood damage reduction measures are usually assessed over a long period of up to 50 years, and the uncertainty surrounding future land use. Also the redistribution may be seen as socially desirable, because flood damages to low-value residential property will be assessed at a higher level making mitigation action more feasible.

Finally, it has not proven possible so far to develop standardized stage-damage curves for industrial concerns due to their enormous variability.

#### **ASSESSMENT OF INDIRECT AND INTANGIBLE DAMAGES**

As the existing "ANUFLOOD" package calculates only direct losses it is appropriate to spend some time on indirect and intangible damages. The remainder of this paper comments on the extent of such losses and assessment difficulties. The "Issues of Economic Efficiency" summarised in Part A are particularly relevant here.

##### **Assessment of tangible indirect damages**

Estimation of indirect damages has proven difficult. Calculations are hampered by lack of data and uncertainty about the transferability of damage estimates from site to site. It is not always clear how data were collected, and no attempts have been made to control for different flood types. A long slow flood with ample warning time for instance, may cause little direct damage, but result in substantially higher indirect costs through prolonged interruption to normal community activities. Type of community and time of year might also be important (Penning-Rowsell & Chatterton, 1977). A coastal tourist town flooded during its peak season would suffer heavy financial losses (Handmer, 1976), while indirect damage from an off-season flood or the inundation of a retirement settlement would be relatively small. Rural communities isolated by flood waters for long periods may incur particularly heavy losses. In view of these factors it is not surprising that estimates of indirect damage range widely up to 75% of direct losses (Table 1).

An important issue in assessment of indirect losses is avoidance of double counting. This has been dealt with in the section on "Economic efficiency". A key point is to beware of counting as an economic loss damage which is a gain or benefit to someone else within the area of analysis. Thus the tourism losses mentioned above might result in heavy financial loss to the flooded operator but other operators in the same region might benefit through increased business. The result might be that there is no net loss to the region. However, there will be distributional effects, in that a flood will make some people better off and others worse off. Benefit-cost analysis ignores these effects, but they should not be ignored in the decision making process. Distributional effects can be shown in a matrix of type of impact by group affected (Figure 2). The geographic and temporal boundaries of the analysis are critical (see Part A).

Table 1: Estimates of tangible indirect residential flood damage as a percentage of actual direct damages.

| SOURCE  | ESTIMATE<br>(% of actual direct damage) | COMMENTS  |
|---|---|---|
| Brisbane<br>(SMEC, 1975)                                    | 15%                                     |   |
| Lismore<br>(Smith <u>et al</u> , 1979)                      | 39%                                     | Includes clean-up   |
| Maitland<br>(McColl <u>et al</u> , 1975)                    | 30-40%                                  | Includes commercial transport and storage costs, and imputed rent |
| Lehigh Valley, USA<br>(Kates, 1965)                         | 15%                                     | Most widely quoted study  |
| Toronto, Ontario<br>(Ontario MTRCA, 1959)                   | 75%                                     | Average figure for residential, commercial and industrial         |
| USA<br>Army Corps of Engineers<br>Department of Agriculture | 15%                                     | )<br>) Quoted in Ontario<br>) MNR and MOH (1977)                  |

|                 | public<br>(shoppers) | shop<br>owner | local<br>flood-free<br>shops | local*<br>economy | national<br>government<br>(tax/relief) | national<br>economy |
|-----------------|----------------------|---------------|------------------------------|-------------------|--|---------------------|
| DIRECT LOSS     | 0                    | -             | +                            | +                 | -                                      | -                   |
| INDIRECT LOSS   | -                    | -             | +                            | +                 | -                                      | -?                  |
| INTANGIBLE LOSS | ?                    | -             | 0                            | -?                | -?                                     | -?                  |

\* Effect on the local economy depends largely on the amount of external (non-local) relief, tax concessions and insurance pay-outs flowing into the area.

Figure 2: Distribution of costs and benefits from minor/moderate flooding. Example of a small shop. Cost = - ; benefit = + ; no change = 0; especially dependent on local circumstances = ? . This figure is a guide only as local circumstances vary greatly..

Green et al (1983b) and Penning-Rowse et al (1984) have summarised the main issues in indirect assessment thus:

VULNERABILITY = (DEPENDENCE, TRANSFERABILITY, SUSCEPTIBILITY)  
 where vulnerability is a measure of the damage, and susceptibility refers to the sensitivity of an activity or facility to the physical presence of flood water. Dependence is a measure of the degree to which the activity requires a particular good or service as an input to function normally, and transferability is "the ability of an activity to respond to a disruptive threat by overcoming dependence either by deferring or using substitutes or relocating" (Penning-Rowse et al, 1984).



It is fairly clear that the size and type of indirect loss is site specific. However, because of the difficulties in obtaining data the usual practice is to treat indirect damages as a fixed proportion of actual direct damage, following the recommendations of Kates (1965). There are some severely limiting assumptions underlying this approach. For example, the relationship between direct and indirect damage is presumed to remain constant as flood stage increases and for different types of flooding, length of warning and so on. Also the extent to which indirect losses are a function of potential rather than actual damages is unclear.

A major project at the Flood Hazard Research Centre, Middlesex Polytechnic is developing a standard method for the assessment of tangible indirect losses. In the period before the Manual's release those undertaking assessments are urged to consult some of the Centre's publications on the subject (Green et al, 1983b; Penning-Rowell et al, 1984).

#### **Assessment of intangible losses**

Most assessments of flood damages and analyses of flood mitigation works contain a brief qualitative statement about the importance of intangible damages. In general no attempt is made either to measure intangibles or to incorporate them into the analysis.

Indeed, the amount of time and energy expended on the various costs and benefits in most flood mitigation studies is directly proportional to ease of measurement: items which are difficult to measure are often left out of the analysis. Usually, it has been left to the political decision makers to assess the value of intangibles.

This does not mean that intangibles are unimportant. In fact there is evidence that in some circumstances they comprise the majority of flood damages (Green et al, 1983a). Mallette (1975) simply asked his interviewees to estimate intangible losses as a proportion of tangible direct damages. Floodplain dwellers averaged 112% of direct losses. His final figure of 94% of direct losses was an average of floodplain and free-free respondents. While this sort of approach may be methodologically deficient the results demonstrate that intangibles are important.

In contrast to monetary evaluation attempts, ranking and matrix procedures acknowledge the non-quantifiable aspects of intangibles, and simply attempt to show whether the damages are large or small and who they affect. While this is useful for evaluating public policy options at one site, the approach is of less value for establishing priorities between sites.

The status of assessment methodology for intangible damages is low, much below that for tangible indirects. Two distinct procedures for intangible flood damage measurement have been presented in the literature. The procedures are summarised below. (Details of the procedure developed by Handmer are found in the Appendix).

One procedure was developed by Handmer (1984) and Lustig (1986) and is set out in detail in Sinclair, Knight and Partners et al (1982). Intangibles are considered in three categories: health effects, disruption and deaths. Loss of memorabilia is not considered separately; it is assumed that when the loss has been great it will emerge as stress induced ill-health. Other direct intangibles omitted include the loss of cultural artefacts. It is expected that these would be assessed separately. Reported ill-health may conceal or include other effects such as work absenteeism, school truancy, increased alcohol consumption etc.

Procedures were devised for the assessment of health effects and disruption on a synthetic standardised basis. Derivation of these are entirely empirical and results are in terms of lost time. The theoretical basis of the method is discussed in Lustig (1986).

For assessment of health effects, data from several sites in Australia and Britain were graphed as the percentage of the floodplain population reporting ill-health following severe flooding by community flood preparedness (Figure A1). Hospital admissions data were also plotted. The proportion of the floodplain population under study expected to suffer ill-health (or be admitted to hospital) can be read off the graph. The estimated proportions are converted to the numbers of people involved at the site under investigation. These numbers in turn are multiplied by factors representing average numbers of days lost per person. The final combined figure gives the total number of days "lost" as a result of self reported ill-health and hospital admissions. Data on

average length of hospital stay are readily available. Time "lost" through self-reported illness is not as readily available, but nevertheless can be obtained for Australia. In the original work a figure was derived by combining the average duration of self-reported disability, average stay in bed and average time off work for these disabilities (Handmer, 1984).

The procedure for assessing disruption is based on material from questionnaire surveys of Echuca and Lismore, NSW, (fully reported in Handmer, 1984). Disruption in days obtained from the questionnaires is divided by three to represent productive time lost. Time lost is plotted against duration of flooding. Minimum loss of time for a severe flood is taken as one day (ie three disrupted days) per adult floodplain resident, and increases with flood duration. The figure thus obtained must be adjusted according to the preparedness of the community under study. Development of the procedure has been hampered by lack of data. It may be that the amount of time lost is very much greater.

In contrast the procedure developed by the Flood Hazard Research Centre, Middlesex Polytechnic, attempts to assess the full range of intangible losses to householders in monetary terms (Green et al, 1983a; Green and Penning-Rowell, 1985).

The Middlesex Polytechnic approach determines, in subjective terms, the relative significance of the various categories of tangible and intangible damage on the household. Householders are asked to rank the magnitude of each type of impact from a flood, damage to the structure, its contents, health effects etc. The procedure assumes that correlations exist between the subjective magnitude of tangible direct losses and their monetary values, and between the subjective magnitude scales used for tangible and intangible damage impact assessment. Assuming that such a correlation exists the intangible impact magnitude can be assigned a monetary value after taking into account flood and household characteristics. "Thus, if the subjective magnitude of, say, £ 1,000 property damage is '3' and an intangible loss is also subjectively assessed as '3', then we might approximately estimate that this household's equivalent loss from this intangible was also 1,000". (Green et al, 1983a). This approach is still very much in the experimental phase.

## APPENDIX

## INTANGIBLE FLOOD LOSSES (drawn from Handmer, 1984)

The following assessment of intangibles is concerned primarily with indirect losses as a result of flood-induced stress. Damages are examined under the headings of health effects, disruption, and deaths. These categories constitute the main types of intangible losses in flood-prone towns throughout Australia. Occasionally other forms of intangible damage will be important, for example the destruction of cultural artefacts during the 1966 Florence flood (Clark, 1983).

Flood related stress may be reflected in ways other than health effects, disruption and deaths, though these are the major categories. For example, disaster stress may precipitate family problems and even breakup, but probably only where the situation was unstable already (Queensland Council of Social Services, 1976). The degree of personal suffering in the post-disaster period, the clean up, and the incidence of ill-health and emotional problems, may be reflected not only in increased strain on all types of facilities, but also by increased work absenteeism, school truancy, alcohol consumption, use of non prescription drugs (Ohlsen et al, 1980), and related crime rates. Not all the effects of disaster are negative. For example, at the individual level, while some family groups may break up, others may be strengthened (Drabek et al, 1973; Raphael, 1979).

## ASSESSMENT OF INTANGIBLE DAMAGES

Previous attempts at assessing intangible damages have been on a site by site actual damage basis and have either assigned a monetary value to the intangibles (Malette, 1975), or incorporated them into the decision making process through a ranking or matrix procedure (Ontario, MNR and MOH, 1977; SKP and MSJKY, 1979).

At least one attempt has been made to assess intangibles using the same procedure as that recommended for indirect damages: as a percentage of actual direct damages. In a floodplain relocation study in Atlanta, Georgia, Malette (1975) asked interviewees to estimate

intangible losses as a proportion of direct damages. The final figure of 94% was an average of floodplain and flood free respondents. These results were used by Johnson (1976) in another relocation study. He took the floodplain intangible damage estimate of 112% of direct losses and added a further 15% of direct damages to incorporate indirect losses; resulting in a final total damage figure of 227% of direct damages (direct, indirect and intangibles). This approach is considered inadequate, although it is an improvement over simply ignoring intangible costs altogether.

In contrast to monetary evaluation attempts, ranking and matrix procedures acknowledge the non-quantifiable aspects of intangibles, and simply attempt to show whether the damages are large or small and who they affect. While this is useful for evaluating policy options at one site the approach is of less value for establishing priorities between sites.

Prototype procedures were devised for the assessment of the intangible losses of health and disruption on a synthetic standardised basis. These are described in detail in SKP et al (1982) and are summarised below. Assessment is in terms of lost time.

## HEALTH EFFECTS

A large body of literature attempts to document the linkages between a range of stressful events and disease. This connection has been particularly well established in relation to heart disease (Dohrenwend and Dohrenwend, 1974), and for widows and widowers, who show significantly increased morbidity and mortality rates, compared to control subjects, in the year following bereavement (Madison and Viola, 1968; Parkes et al, 1969; Stein and Susser, 1969). Other examples are provided by Rahe (1972) and Dohrenwend & Dohrenwend (1974). Rabkin and Struening (1976) critically review the methodology typically employed by these "life events" studies, and point out the numerous deficiencies.

However, they accept that, although the cause and effect process remains obscure and a clear physiological explanation has yet to be provided, "it is becoming recognised that stress can be one of the components of any disease, not just of those designated as psychosomatic ..." (Rabkin and Struening, 1976). The effects of stress, at both the

individual and community level, depend on a variety of factors which can include event predictability, speed of onset and magnitude, degree of preparedness, past experience, perception of the event as stressful, strength of family and broader social support systems, and a range of individual and personality factors.

It would appear reasonable to assume that a major flood or other natural disaster would produce stress which in turn could precipitate a range of health problems. Many workers have examined the effects of disaster on mental health, the studies include Titchener and Kapp (1976), Erikson (1976), Quarantelli and Dynes (1977), Chamberlin (1980), Bromet and Dunn (1981), Ahearn (1981), Glesser et al (1981) and Bolin (1982). Studies on the health effects of flooding, while limited in number, are broad in scope. The described effects range from the increased incidence of headaches and emotional problems (Poulshock and Cohen, 1975), to substantial rises in the levels of leukemia, lymphoma and spontaneous abortion (Janerich et al, 1981), and mortality (Lorraine, 1954; Bennet, 1970). The studies by Bennet (1970), Abrahams et al (1976), and Handmer & Smith (1983) (also see Smith et al, 1980) will be examined in more detail.

Bennet's study of the 1968 Bristol, UK, floods is the most widely quoted. Certainly his study appears to be the most rigorous research in the field, with its use of multiple data sources and a well controlled sample. His results demonstrated that the Bristol flood had a major impact on health (Table A1). "There was a 50% increase in the number of deaths among those whose homes had been flooded, with a conspicuous rise in deaths from cancer. Surgery attendances rose by 53%, referrals to hospital and hospital admissions more than doubled. In all respects the men appeared less well able to cope with the experiences of disaster than the women".

Abrahams et al (1976) set out to test whether Bennet's results held for Brisbane following the serious flooding of 1974. The sole data source was a set of interviews administered to a sample of flooded and non-flooded people, contacted some months after the flood and again approximately one year later. Results show that "the number of visits to general practitioners, hospitals, and specialists were all significantly increased for flooded persons in the year following the flood".

Table A1: Hospital admissions following the Bristol flood (Bennet, 1970).

|                                 | Numbers admitted to hospital |                                     | Flooded and not flooded compared                                      |
|---------------------------------|------------------------------|-------------------------------------|---|
|                                 | Flooded N = 209              | Not flooded N = 238                 |   |
| 11 July 1967 to<br>10 July 1968 | 3<br>(actual value)          | 10<br>(hypothetical value)//        | 11<br>Using actual value P = 0.046#<br>Using hypothetical value, N.S. |
| 11 July 1968 to<br>10 July 1969 | 23                           | 12                                  | x <sup>2</sup> = 4.69*<br>p > 0.05                                    |
|                                 | Using actual value           | x <sup>2</sup> = 14.8*<br>p < 0.001 | N.S.  |
| Before and after compared       | Using hypothetical value     | x <sup>2</sup> = 4.74*<br>p < 0.05  |   |

# Fisher's exact probability.

// This value is the admission rate for the not-flooded group applied to flooded group. The calculation was made because the admission rate of the flooded group was very low before the flood. Using this value the difference in the admission rate before and after the flood is still significant.

\* Chi squared values.

The Bennet and Abrahams et al studies demonstrated the negative impact on health of severe floods in inexperienced communities. In an attempt to check the degree to which their results held for an experienced population Handmer and Smith (1983) examined the effects of major flooding on hospital admissions rates and mortality in Lismore. The major findings are that while the flood does not appear to have increased the number of hospital admissions or deaths, in an area well adjusted to floods, it has affected the pattern of admissions. Among those who had more than 1m of water through their homes, the number of male admissions doubled and the number of female admissions halved. Similar gender related effects, -

though not as marked as in Lismore, were also found by Bennet (1970) and Abrahams et al (1976). This well documented impact of floods on health is puzzling, and a satisfactory explanation has not been forthcoming.

In addition to these major studies, useful site-specific information has been collected as part of Australian flood damage studies in Lismore (Smith et al, 1979), Shepparton-Mooroopna (Kinhill Pty Ltd, 1981), Wangaratta (Finlayson and McKay, 1980), and Brisbane (Queensland Council of Social Services, 1976).

### **Assessment of health effects**

Unfortunately, many studies are not strictly comparable to the degree required to develop a predictive model. The method of investigation and types of controls vary greatly. Some work makes no attempt to examine or control for the predisposing/mediating variables found to be important in other stress research. However a reasonable number of Australian studies, while not uniform in terms of methodology or quality, are broadly comparable for self reporting of ill-health. Summary results from these studies are presented in Tale A2. These data were used by the author to produce a prototype synthetic method for assessing the extent of ill-health induced by the stress associated with severe flooding. The full procedure and examples of its application are contained in SKP et al (1982). The suggested method has the basic advantages and problems of synthetic direct damage assessment discussed earlier.

In brief the procedure is as follows. The data in Table A2 are graphed as the percentage of the floodplain population reporting ill health following severe flooding by community flood preparedness (Figure A1). Hospital admissions data are also plotted. Preparedness is taken as the percent of the flooded population with prior flood experience at their present address. Information that can be deduced, if necessary, from census material. The proportions of the floodplain population estimated to suffer ill health, and to be admitted to hospital, are converted to the numbers of people involved at the site under investigation. These numbers in turn are multiplied by factors representing average numbers of days lost per person. The final combined figure gives the total number of days



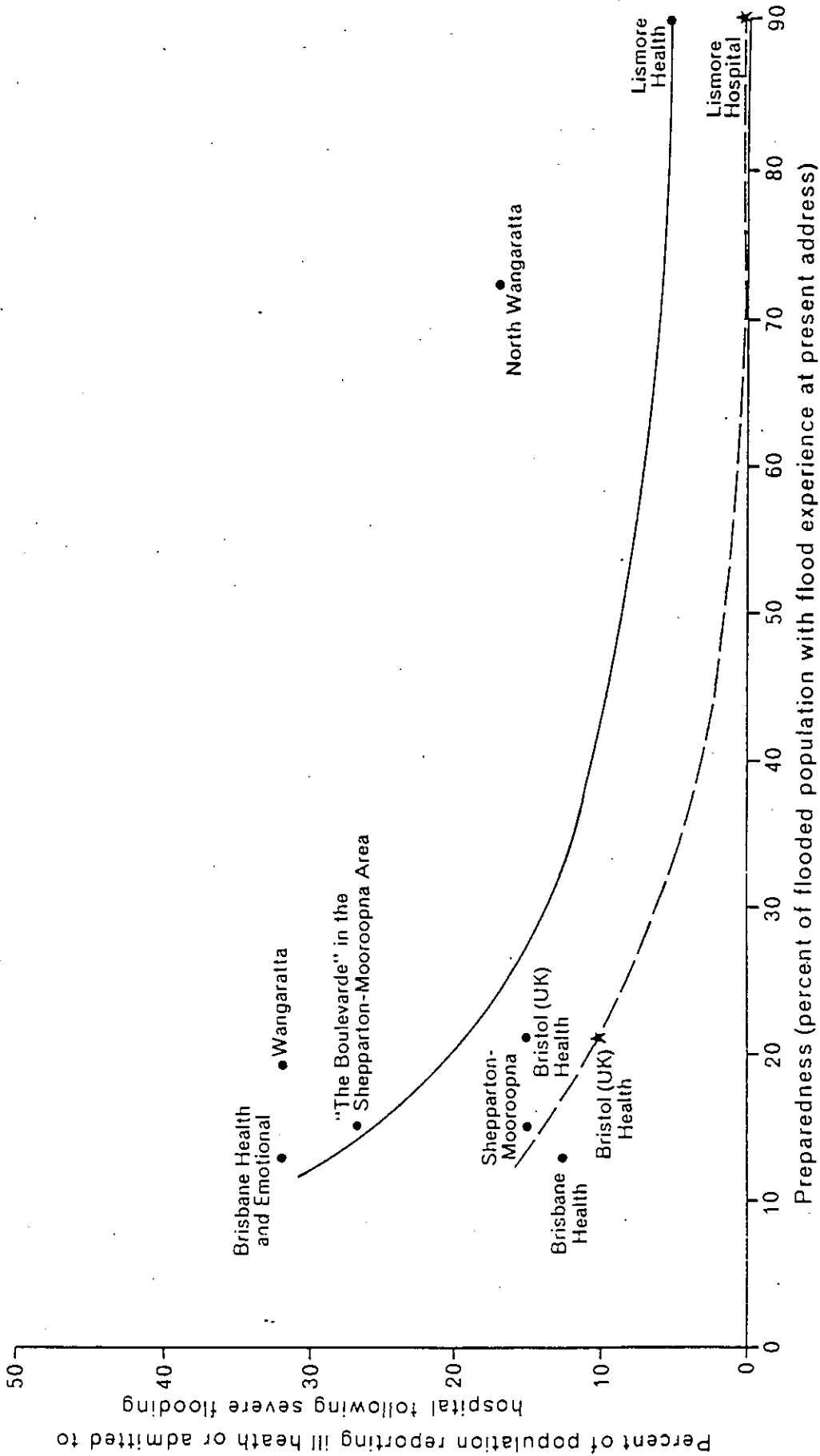


Figure A 1 : Effect of preparedness on ill-health following flooding. Calculation of preparedness is described in SKP et al (1982).

Table A2: Ill-health following floods (size of sample is indicated in brackets)

| SELF-REPORTING OF ILL-HEALTH  |  |  |
|---|--|--|
|   | % of Floodplain<br>Population<br>Affected        | Preparedness (% with Flood<br>Experience at Present<br>Location) |
| LISMORE (N=150)<br>(Smith et al, 1979)  | 6  | 90   |
| BRISBANE (N=6007)<br>(QCSS, 1976)*  | 13 (health)<br>32 (health &<br>emotional)        | 15   |
| WANGARATTA<br>North Wangaratta (N=118)<br>One Mile Creek (N=360)<br>(Finlayson & McKay, 1976) | 17<br>32   | 72<br>19   |
| SHEPPARTON-MOOROO PNA<br>(N=532)<br>(Boulevard sub-area)<br>(Kinhill, 1981)                   | 14<br>27   | 15<br>15   |
| BRISTOL (UK) (N=197)<br>(Bennet, 1970)  | 15   | 20<br>estimate by Smith<br>& Finlayson<br>(pers.comm., 1982)     |
| HOSPITAL ADMISSIONS   |  |  |
|   | Increase as<br>a % of Flood-<br>plain population | Preparedness   |
| LISMORE (N=300)<br>(Handmer & Smith, 1983)  | 0  | 90   |
| BRISTOL (N=209)<br>(Bennet, 1970)   | 10<br>(recorded values)                          | 15-20  |

\* Queensland Council of Social Services (1976).

"lost" as a result of hospital admissions and self reported ill health. Factors of 7.5 and 3.4 days are conservative figures derived from published Australian Bureau of Statistics data, and refer respectively to average length of hospital stay (ABS 1981(a): 64), and the average period a self reported illness was debilitating (ABS 1981(b)). Disability time is a combination of average length of self perceived disability, average stay in bed and average time off work, weighted for the proportion of time off work or in bed.

### DISRUPTION

Flood damage studies have tended to ignore intangible damages resulting from disruption. However, an Australian study by McColl Ptns Pty Ltd (1977) is largely devoted to this type of intangible damage. They found that in rural areas where the flood duration was long, the major issue was the problem of travel and communications, especially the disruption of schooling for children, and isolation of families from neighbours and town services. Where the flood duration was short, clean-up time is relatively more important.

Both issues result in lost time. For example a flood may effectively maroon a family in western NSW for weeks or even months. Although some day-to-day activities would continue, disruption and stress may be substantial. Some limited data has been obtained from questionnaire surveys in the towns of Lismore and Echuca which asked the question, "For how long does a flood disrupt your normal routine?". Lismore, represents coastal, or short duration, flooding; and Echuca, relatively slow inland flooding. Although the data are sparse, some trends can be discerned. For areas with long, slow floods, the people seem not to regard themselves as severely disrupted after the first few days, even though they are surrounded by water. For example, they do not look on having to use a boat or tractor for transport as a major disruption, since they are still able to go about many of their normal activities. Consequently, it is likely that there is an upper bound to the period of disruption, at least for well-prepared communities. For less prepared communities, it is judged that the period of disruption would be greater, but no information on this has been collected.

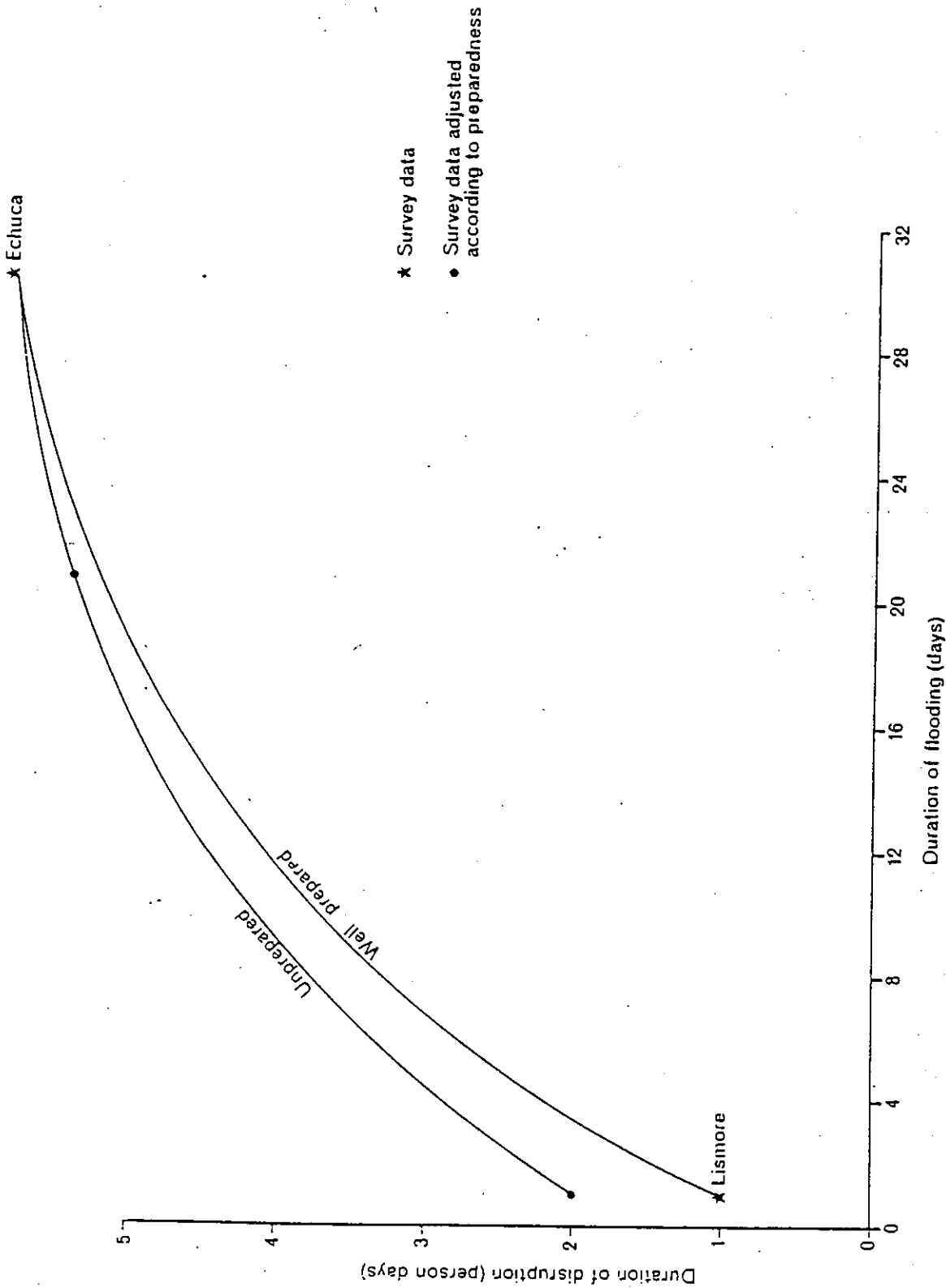


Figure A2 : Disruption (time lost) by duration of flooding. Results shown for both prepared and unprepared communities. Calculation of preparedness is reviewed in SKP et al. Data from the Lismore and Echuca surveys.

For settlements subject to long periods of inundation, the warning times would themselves have been long, so that even if a community was initially unprepared, it should have improved its readiness by the time the flood arrived. Hence, for long durations of flooding, the time lost through disruption may be relatively independent of the initial preparedness.

### Assessment of disruption

An attempt by the author to develop a synthetic method for assessing the duration of flood caused disruption is presented in SKP et al (1982), based on material from surveys in Lismore and Echuca. The disruption in days obtained from the questionnaires is divided by three to represent productive time lost. Time lost is plotted against duration of flooding (Figure A2). Minimum loss of time for a severe flood is taken as one day (ie three disrupted days) per adult floodplain resident, and increases with flood duration. The figure thus obtained must be adjusted according to the preparedness of the community under study. Development of the procedure has been hampered by lack of data and the outlined method should be treated as preliminary only.

### DEATHS

Deaths due to flooding may be a result of drowning or flood induced stress.

#### Deaths from drowning

Deaths directly attributable to flooding in Australia have been rare with only some 80 deaths over the last 40 years. When deaths have occurred they have generally been as a result of severe flash flooding of transportation routes, such as the Woden Valley flood of 1971 (7 deaths); or of a major flood affecting an inexperienced and unprepared population, eg Brisbane 1974 (12 deaths). Even in these cases mortality has been small compared with flood disasters elsewhere. There is no Australian trend towards increasing numbers of flood related deaths as is evident in North America (Natural Hazards Observer, June 1978:4).

Key factors in maintaining this situation are the identification of potential flood disaster sites, avoidance of high risk (especially coastal) areas, and the development of effective warning systems. Typically the greatest risks are associated with: the sudden flooding of transportation routes, flash flooding of urban creeks, or sudden levee collapse.

#### **Mortality increase from flood related stress**

That mortality may increase substantially after flood disasters has been well established.

"There were a large number of deaths (sic) in Luzerne and Wyoming Counties after the flood (Hurricane Agnes). Statistics compiled showed a dramatic rise in the number of deaths over comparable periods for the past three years, primarily due to heart disease. Such data suggest that severe emotional trauma, which carries with it a sense of hopelessness and despair, speeds one's trajectory toward the grave" (McGee and Heffron, quoted in O'Malley, 1978:19).

The most convincing work is that by two British researchers, Bennet (1970) and Lorraine (1954). Bennet found a greatly increased mortality rate for areas of Bristol flooded in 1968: a rise of 50% in the year following flooding (Table A3). There was effectively no change for the rest of Bristol over the same period making the increase significant for Chi-square at the 0.02 level. In his study of the Canvey Island flood disaster Lorraine found a similar, though at 24% a less marked, increase in mortality for the year following flooding. As stress is expected to precipitate rather than actually cause death (Rabkin and Struening, 1976), a decrease in mortality rates should be observed during the second year after flooding. No figures are available for Bristol's floodplain, but the hypothesis is clearly supported by Lorraine's (1954) study for which Bennet obtained 1954 mortality figures. Table A3 shows that in 1954, the second year after the Canvey Island flood disaster mortality was substantially less than normal.

Attempts to obtain similar results following severe floods in Australia have not been successful. The fact that there was no overall increase in mortality in Lismore following the 1974 flood is not altogether surprising (Handmer & Smith, 1983; Smith et al, 1980), given

Table A3: Numbers of deaths in Bristol and Canvey Island before and after flooding. (Data from Bennet, 1970). Those who drowned during the floods are excluded from the calculations

## BRISTOL\*

|             | Year before flood | Year after flood | % Change     |
|-------------|-------------------|------------------|--------------|
| Flooded     | 58                | 87               | 50% increase |
| Non-flooded | -                 | -                | no change    |

\* Change significant at 0.02 level (chi-squared = 5.65, D.F. = 1)

## CANVEY ISLAND\*

|                         | Before flood |      | After Flood |      |
|-------------------------|--------------|------|-------------|------|
|                         | 1951         | 1952 | 1953        | 1954 |
| Flooded and non-flooded | 151          | 147  | 183         | 135  |

\* Change significant at 0.001 level (chi-square = 18.60, D.F. = 1)

the community's exceptionally high level of flood experience and preparedness. Experience and adequate preparedness act to mediate the effects of stressful events (Smith et al, 1980). Also such mediating factors may affect individual perception of flooding. Perception of the event as stressful by the affected individual has been found to be a key factor in determining the effect of stress (Dohrenwend and Dohrenwend, 1974; Rabkin and Struening, 1976). Unlike Lismore the Brisbane community was inexperienced and largely unprepared for the severe 1974 floods. Hence a significant number of stress induced deaths could reasonably be expected. However, Abrahams et al (1976) failed to find any evidence of increased mortality in the year following flooding. But the number of deaths, a total of 15 in both their flooded and non-flooded sample groups, is considered too small for firm conclusions. Unlike the other three post-flood mortality studies Abrahams et al did not consult death certificates, instead they relied on deaths within their survey samples - hence the small number and sampling uncertainty surrounding the results.

Assuming that the results of Abrahams et al (1976) accurately reflect the Brisbane situation a number of factors may be responsible for the mortality figures of the English studies. Climate differences may be important in increasing stress. Certainly Canvey Island in mid-winter and even summer in Bristol is very different from Brisbane's subtropical climate. For Bristol the higher proportion of older people in the floodplain area may be significant in comparisons with Brisbane. Older people tend to be more prone to disaster-induced stress (Dodge and Martin, 1970; Price, 1978), especially if evacuated for substantial periods (Edwards, 1976; Raphael, 1979). Another potentially important factor for post-flood mortality in events directly responsible for a large number of deaths, such as the Canvey Island flood where 58 drowned, is the increased risk of death among the bereaved in the year following the disaster (Parkes et al, 1969).

#### **Valuing loss of life**

No procedures are recommended. Instead human safety should be paramount in planning decisions.



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